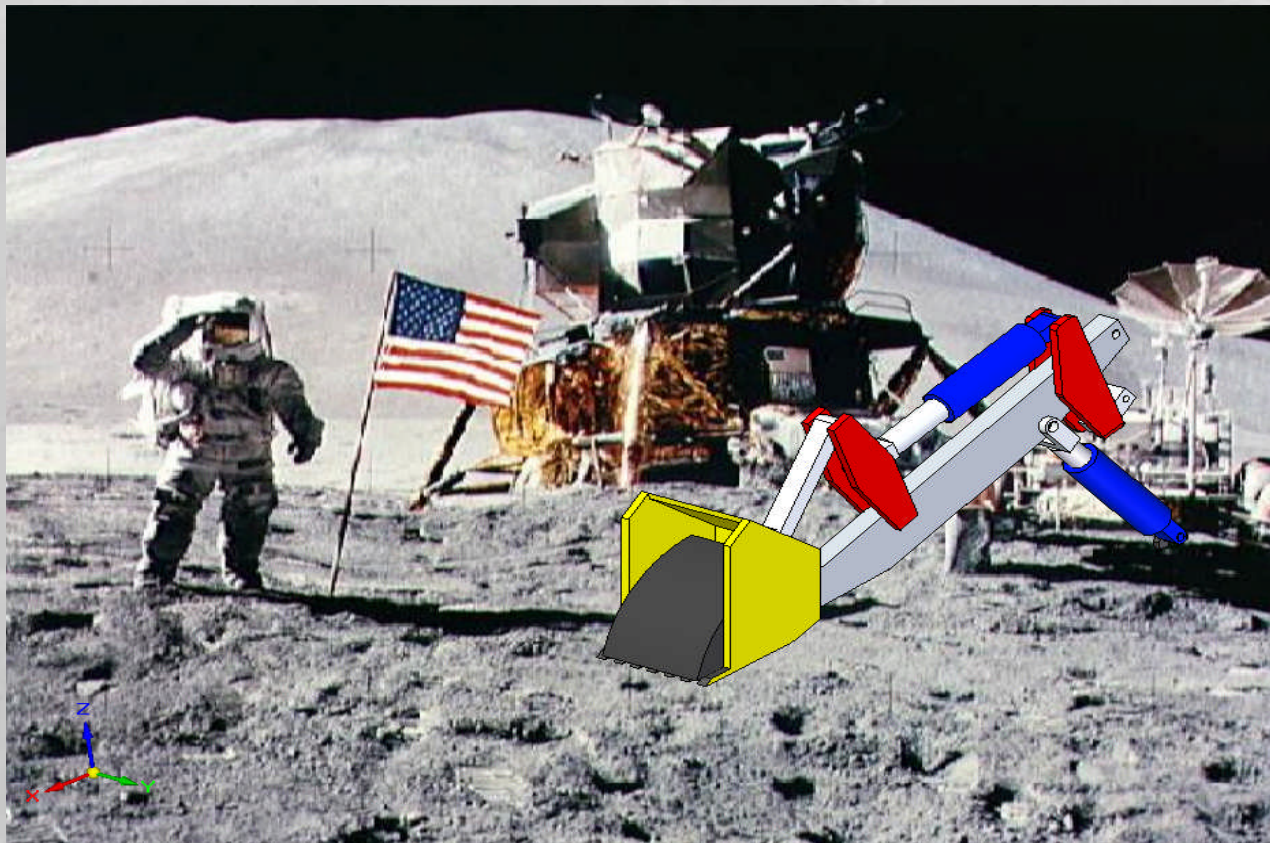
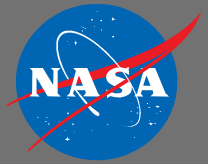


Webpage and Lunar Handbook for NASA Student Capstone Projects

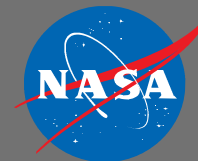
David Beale – Auburn University dbeale@eng.auburn.edu, 334-844-3336



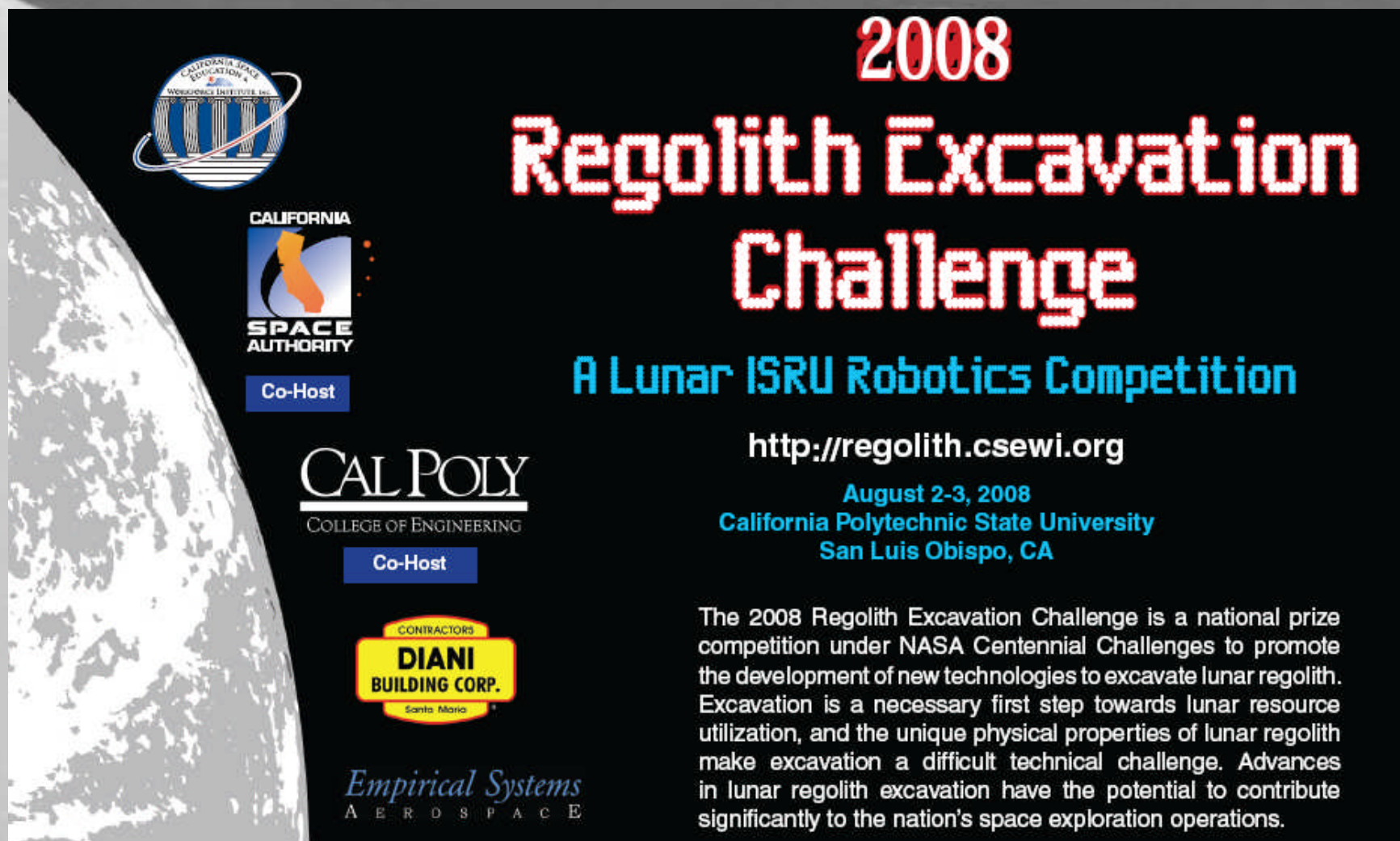


Objective

- ▣ From ESMD site: “this project will investigate concepts for Lunar Regolith Excavation equipment and propose solutions in the form of completed designs and prototypes”, using a Systems Engineering Approach
- ▣ Topic: “Lunar Regolith Excavation for Oxygen Production and Outpost Emplacement”
- ▣ Gloria Murphy: “Cover the Systems Engineering”
- ▣ Rob Mueller: “Cover the Lunar Environment”



\$750K Lunar Challenge

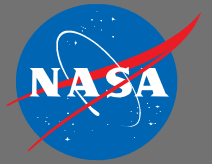
A promotional poster for the 2008 Regolith Excavation Challenge. The background is a grayscale image of the Moon's surface. The poster includes logos for the California Space Education & Workforce Institute, California Space Authority, Cal Poly College of Engineering, and Empirical Systems Aerospace. It also features the NASA logo. The main title is "2008 Regolith Excavation Challenge" in a large, red, pixelated font. Below the title is the subtitle "A Lunar ISRU Robotics Competition" in a blue, pixelated font. The website "http://regolith.csewi.org" is listed, along with the dates "August 2-3, 2008" and the location "California Polytechnic State University, San Luis Obispo, CA". A paragraph of text describes the challenge as a national prize competition under NASA Centennial Challenges to promote the development of new technologies to excavate lunar regolith.

2008
Regolith Excavation
Challenge
A Lunar ISRU Robotics Competition

<http://regolith.csewi.org>
August 2-3, 2008
California Polytechnic State University
San Luis Obispo, CA

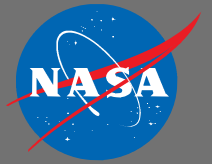
The 2008 Regolith Excavation Challenge is a national prize competition under NASA Centennial Challenges to promote the development of new technologies to excavate lunar regolith. Excavation is a necessary first step towards lunar resource utilization, and the unique physical properties of lunar regolith make excavation a difficult technical challenge. Advances in lunar regolith excavation have the potential to contribute significantly to the nation's space exploration operations.

Logos:
- California Space Education & Workforce Institute
- California Space Authority
- Cal Poly College of Engineering
- Empirical Systems Aerospace
- NASA



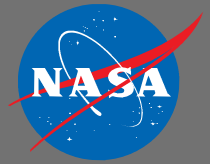
Previous Student Excavators

- Three student teams created two excavators that were driven by a Gator
- Cost: About \$6K per student group. NASA covered costs of materials.
- Last group included EE students with the ME students, making the project multidisciplinary and with several subsystems. Nice project for Systems Engineering
- NASA is planning on a competition next year at KSC.
- I'm not going to show you their prototypes



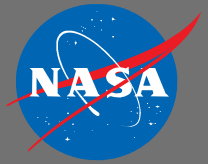
Is Your Situation My Situation?

- ✓ **I teach a senior project class (“capstone design”), guiding teams of students assigned to projects.**
- ✓ **2 semesters long, 2 CH/semester**
- ✓ **Course is intended to have minimal or no lecturing – students are expected to spend their time designing and building a prototype.**
- ✓ **Faculty guides the student team through the design process. We offer no “innovation”**
- ✓ **Project could, but not necessarily, be multidisciplinary (single subsystem or many subsystems).**
- ✓ **The ESMD course material is tailored to this situation!**



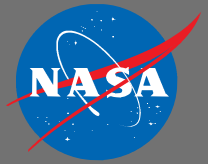
The Webpage

- This webpage contains the "**Lunar Engineering Handbook**", which is composed of the following chapters:
- Chapter 1: Introduction to Lunar Excavator Design for Senior Project Students [Chapter1.htm](#).
- Chapter 2: Systems Engineering – The Systems Design Process [Chapter2.htm](#)
- Chapter 3: Systems Engineering Example of a Cube Satellite [Chapter3.htm](#)
- Chapter 4: Systems Engineering Tools [Chapter4.htm](#)
- Chapter 5: The Lunar Environment and Issues for Engineering Design [Chapter5.htm](#)
- Chapter 6: Component and Material Selection [Chapter6.htm](#)
- Chapter 7: Thermal Considerations of Lunar Based Systems [Chapter7.htm](#)
- Chapter 8: Computer-Aided Engineering Tools [Chapter8.htm](#)



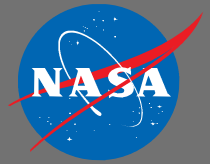
And Then there is Chapter X

- Much of the handbook is meant to be a resource. No one expects students to read the whole thing.
- Certain chapters are better than others. In the future Chapters 6 and 8 could be expanded and improved.
- Chapter X takes advantage of hyperlinks to condense the material into a chronological design sequence; it is a roadmap for a senior projects multidisciplinary team designing an excavator. In Chapter X is background information about the moon and lunar environment, with a condensed and accelerated presentation of the Systems Engineering Process.



The Best Way to Use this Material in Your Project

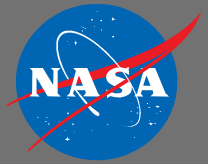
- Assign reading of Chapter X, 2 and 5 to the students. Students and professor could read and click through Chapter X together during class time if it is scheduled in a computer lab. Chapter 2 is particularly important and needs to be thoroughly understood since students will be applying Systems Engineering. Chapter 5 covers the lunar environment. This all should take between 1-2 weeks. Next students start designing, practicing what was learned in Chapter 2. And use the rest of the chapters as reference material to be called upon when needed.
- For those who wish to learn Systems Engineering only and have no interest in the moon, Chapter 2 was created to function by itself as a concise presentation of Systems Engineering.



The Lunar Engineering Handbook and Webpage

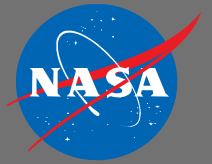
<http://www.eng.auburn.edu/~dbeale/ESMDCourse/>

- ▣ **On Systems Engineering (SE):** Provides background by a brief, but complete SE **guidebook** chapter (Chapter 3) for a student-team Systems Engineering Project.
 - Student Friendly, with lots of examples and direction meant to simplify a complex process and applying it.
 - Co-authored by a NASA Systems Engineer.
 - Strongly influenced by a special NASA SE course developed and tested at Univ of Texas Spring 08, by a NASA engineer with 20 years experience in SE.
- ▣ **On the Lunar Environment:** Provides background on past and future lunar missions, lunar environment, materials and components, thermal control, CAE



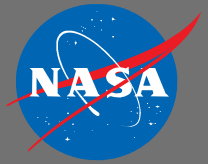
Overview of Chapter 1: Introduction

- Best reference: The “Lunar Sourcebook” (on CD) and The Lunar Base Handbook
- Objective: Provide background. Excite students. Students have little knowledge about what happened in early lunar missions, rovers are fun and legacy, neat lunar bases, teleoperated and autonomous “robonaut”, “chariot”.



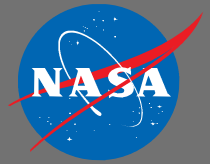
Overview of SE Chapter 2-4

- Best references: NASA SE Handbook as a reference, U of Texas Course notes.
- Systems Engineering literature is a mess, particularly if you want to apply it and learn it quickly. Complex and inconsistent terminology.
- Big challenge: How to simplify SE, and apply on a student project?
- Sought help from experts with lots of experience: Dick Cook, Lisa Guerra, Joe Bonometti, JM Wersinger
- It is possible to use these chapter for any SE student project!!!



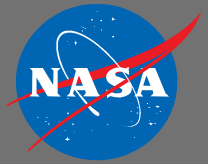
A Single Formula for SE

- The Vee Chart: “Vee Chart” for the lifecycle, from –A through D
- The 11 SE functions: NASA Document GPG7120: Used this and description of 11 SE functions
- Use of simple SE tools
- Lots of examples showing how to write requirements, create architectures, interfaces, etc.



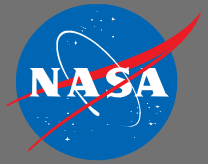
Chapter 5 – The Lunar Environment – very important information here

- 1 The Lunar Environment and Issues for Engineering Design
- 1.1 Gravity and the Lunar Vacuum
- 1.2 The Lunar Day and Night
- 1.3 Radiation
- 1.3.1 Electromagnetic and Particle Radiation (Smithers, 2007; Tribble, 2003)
- 1.3.2 Ionizing Radiation
- 1.3.3 Radiation and Survivability
- 1.4 Surface Temperature
- 1.5 Micrometeoroids
- 1.6 Regolith
- 1.6.1 General Characteristics
- 1.6.2 Other Physical Properties
- 1.6.3 Chemistry
- 1.6.4 Geotechnical and Engineering properties
- 1.6.5 Regolith Simulants
- 1.7 Summary of Lunar Resources
- 1.8 APPENDIX – DRAFT SOIL AND ROVER FORCE CALCULATIONS



Chapter 6: Material and Component Selection

- ▣ Best Reference: Conley (Satellites), Lunar Rover pages at LPI
- ▣ When designing the excavator, not much guidance is available in the literature for lunar components, so turned to space engineering literature that focused on satellites.
- ▣ The Lunar Rover represents “legacy”, students can view a successful lunar product
- ▣ I sent students out to do “trade studies”, looking at materials for a bit, conveyor belt, support structure, etc.
- ▣ Found and listed a number of standards
- ▣ Considered fasteners, bearings, motors, power components



Chapter 7 : Thermal Control

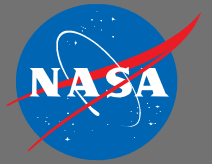
- **A special chapter covering the thermal aspects of the lunar environment and methods to analyze and mitigate the harsh temperature conditions.**
- **Prepared by Dan Harris, who has worked in satellite thermal control for many years.**



Chapter 8: CAE Tools (demonstration only)

Modeling and simulating is often used in the design phases of Systems Engineering

Demonstrated a multi-body dynamic simulation of a excavator using Dynamic Designer



A “How to” for an Excavator Project

Get a mission objective and NASA stakeholder

Get money in place for materials

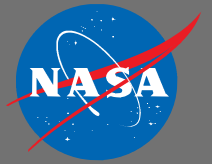
Contact other faculty at your university to create a multidisciplinary team (although you can run just an ME team with a mechanical excavator missions objective)

Design and build for one or two semesters (excavator may mate to KSC vehicle)

Test in bin full of dry concrete.

Compete at KSC in 2010???

Send video to NASA+ report



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- <http://www.eng.auburn.edu/~dbeale/ESMDCourse/>

